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Mishima et al.

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(54) **LITHOGRAPHY APPARATUS, ALIGNMENT METHOD, AND METHOD OF MANUFACTURING ARTICLE**

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(51) **Int. Cl.**

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G03B 27/42	(2006.01)
G03F 9/00	(2006.01)
G03F 7/20	(2006.01)
G03F 7/00	(2006.01)

(52) **U.S. Cl.**

CPC ***G03F 9/7042*** (2013.01); ***G03F 7/0002*** (2013.01); ***G03F 7/70141*** (2013.01)

(58) **Field of Classification Search**

CPC G03F 7/70141; G03F 9/7042
USPC 355/52, 53, 55, 67; 356/399–401
See application file for complete search history.

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(57) **ABSTRACT**

The present invention provides a lithography apparatus for transferring a pattern formed on an original to each of a plurality of shot regions on a substrate, comprising a detection unit configured to detect a mark provided in the shot region and a mark provided on the original, and a control unit configured to control alignment between a target shot region and the pattern of the original such that the mark in the target region detected by the detection unit and the mark on the original are shifted by a positional shift amount which is generated between each mark in the shot region and each mark on the original when an overlay error between the shot region and the pattern of the original falls within an allowable range.

12 Claims, 11 Drawing Sheets

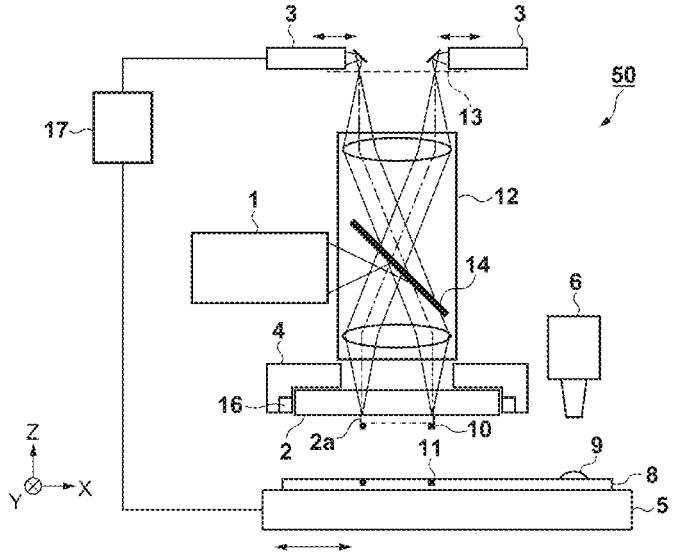

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FIG. 1A

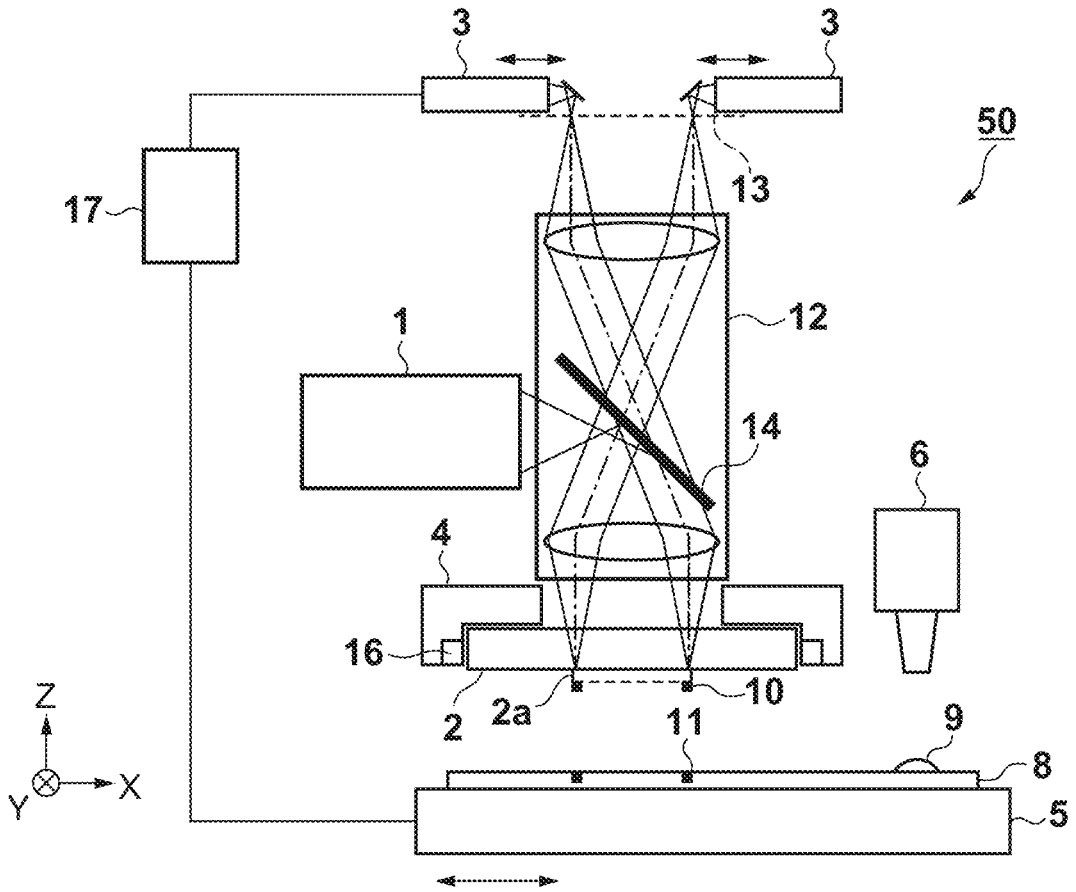


FIG. 1B

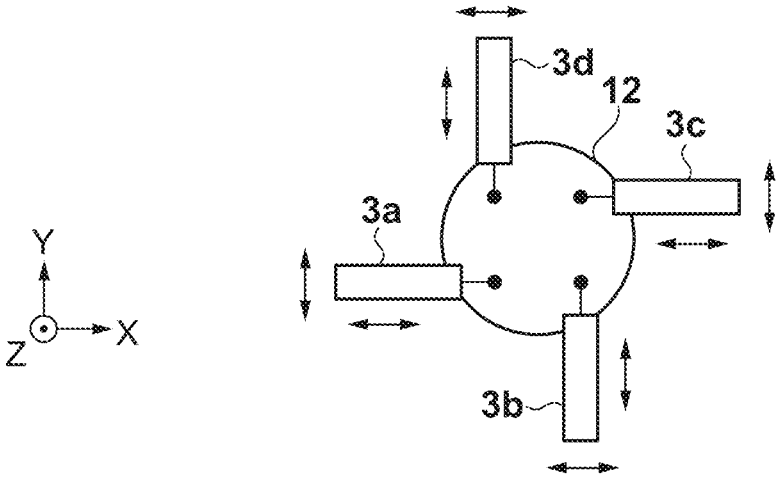


FIG. 2

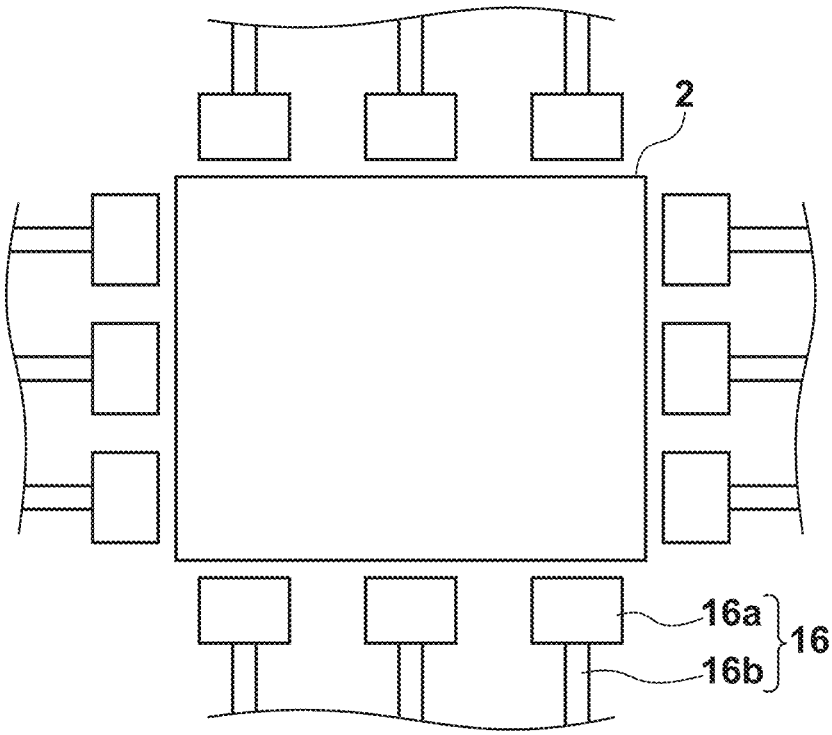


FIG. 3A

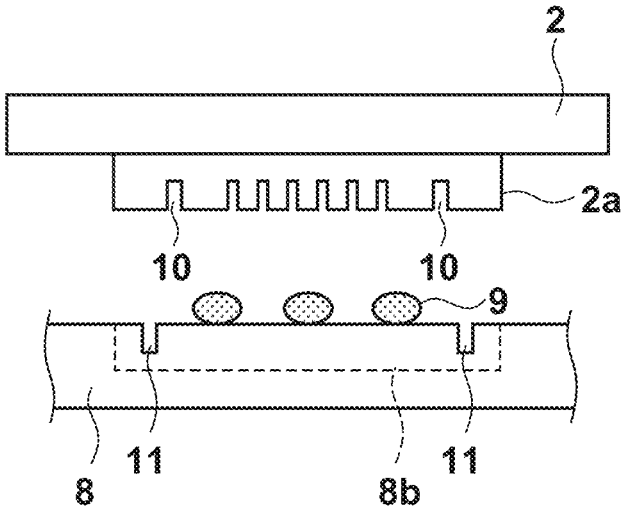


FIG. 3B

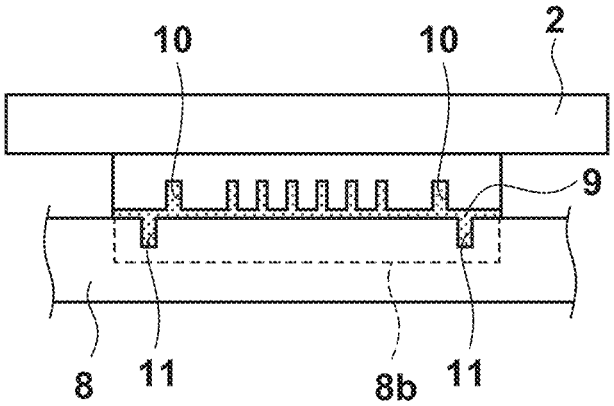


FIG. 3C

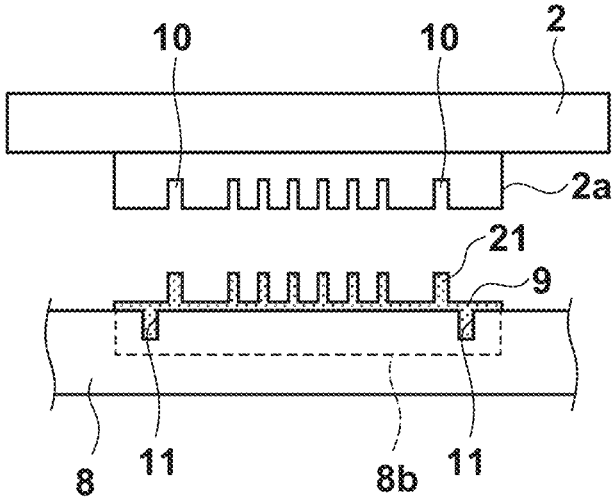


FIG. 4

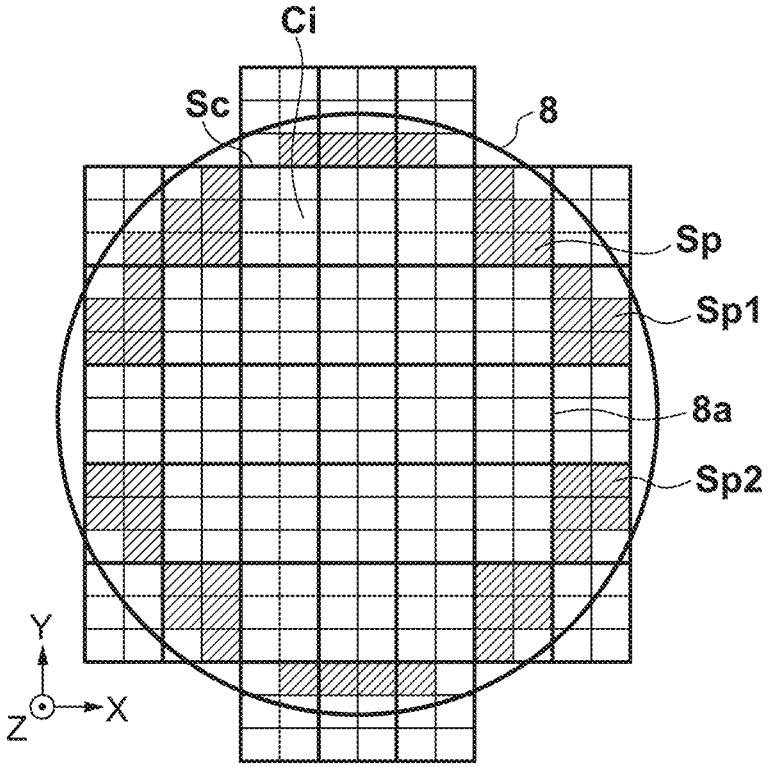


FIG. 5

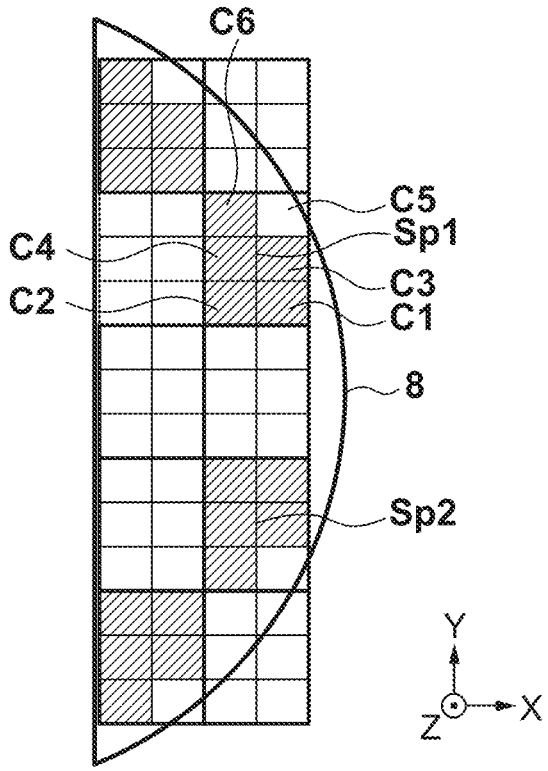
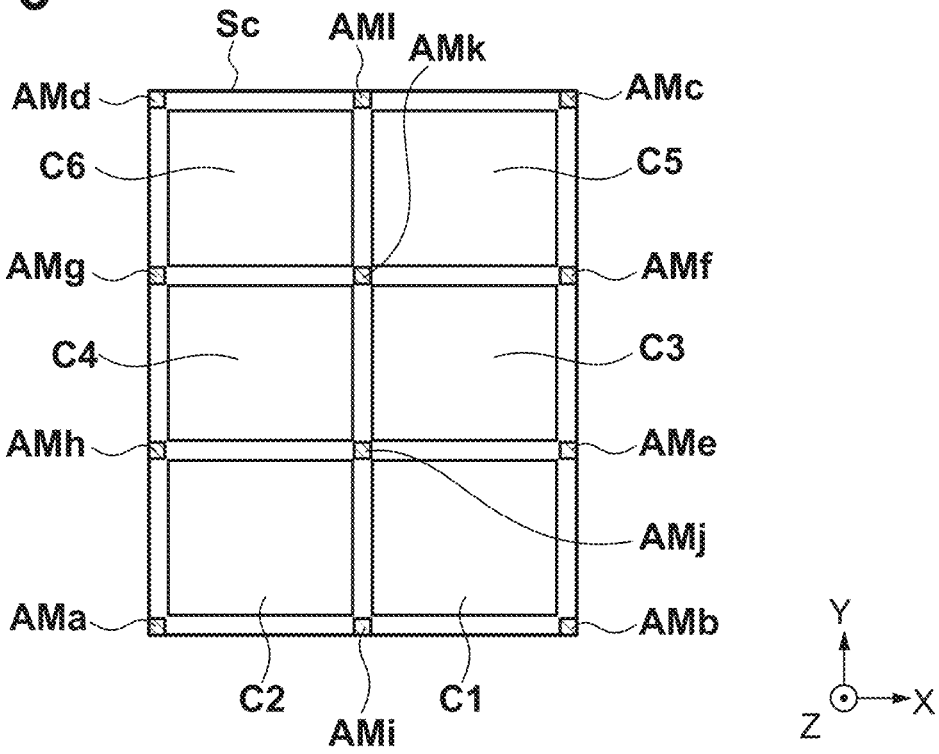


FIG. 6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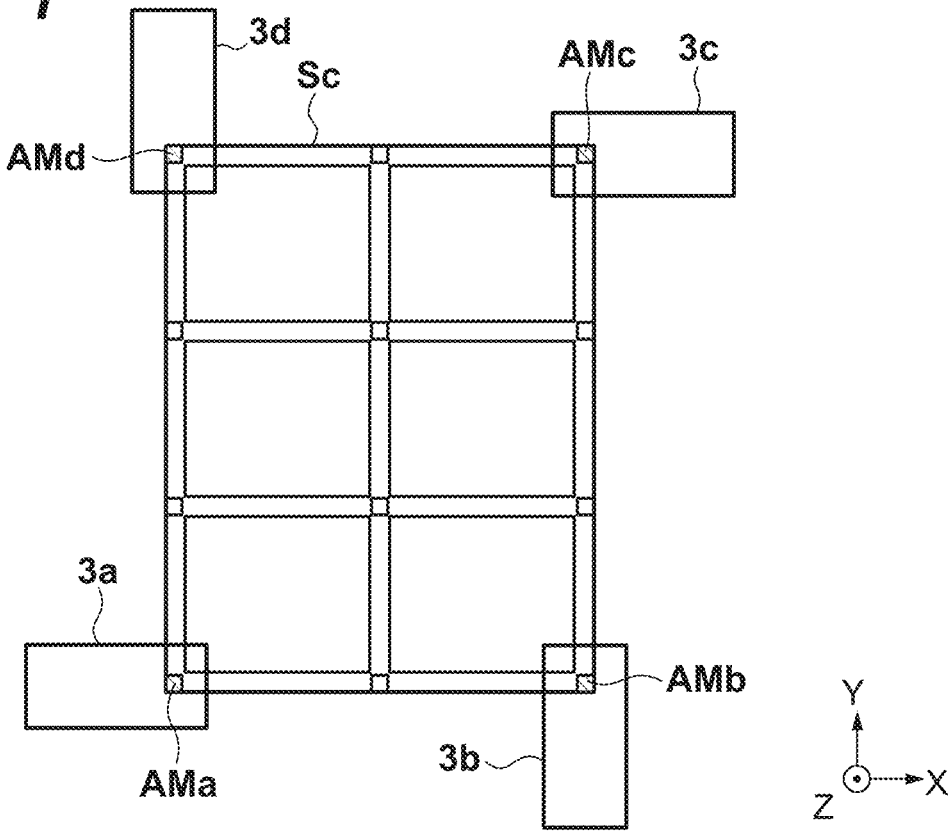
AMl
AMk
AMd
AMc
C6
C5
AMg
AMf
C4
C3
AMh
AMe
AMj
AMa
AMb
C2
AMi
C1
Y
Z
X

FIG. 7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Sc
AMc
3c
AMd
3a
AMb
3b
AMa
Y
Z
X

FIG. 8

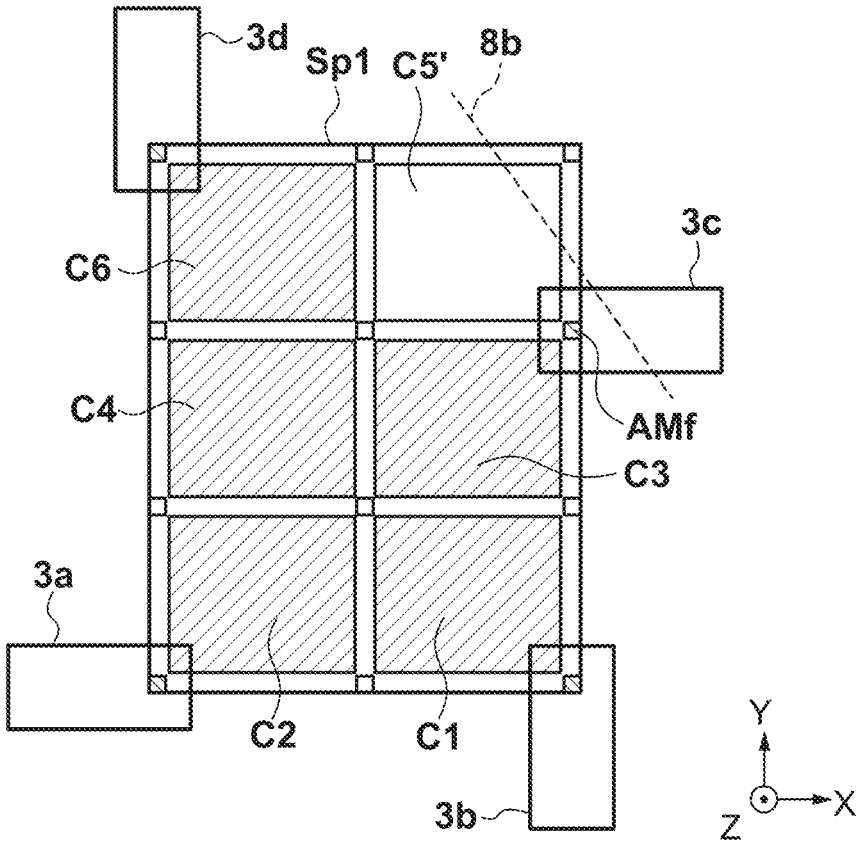
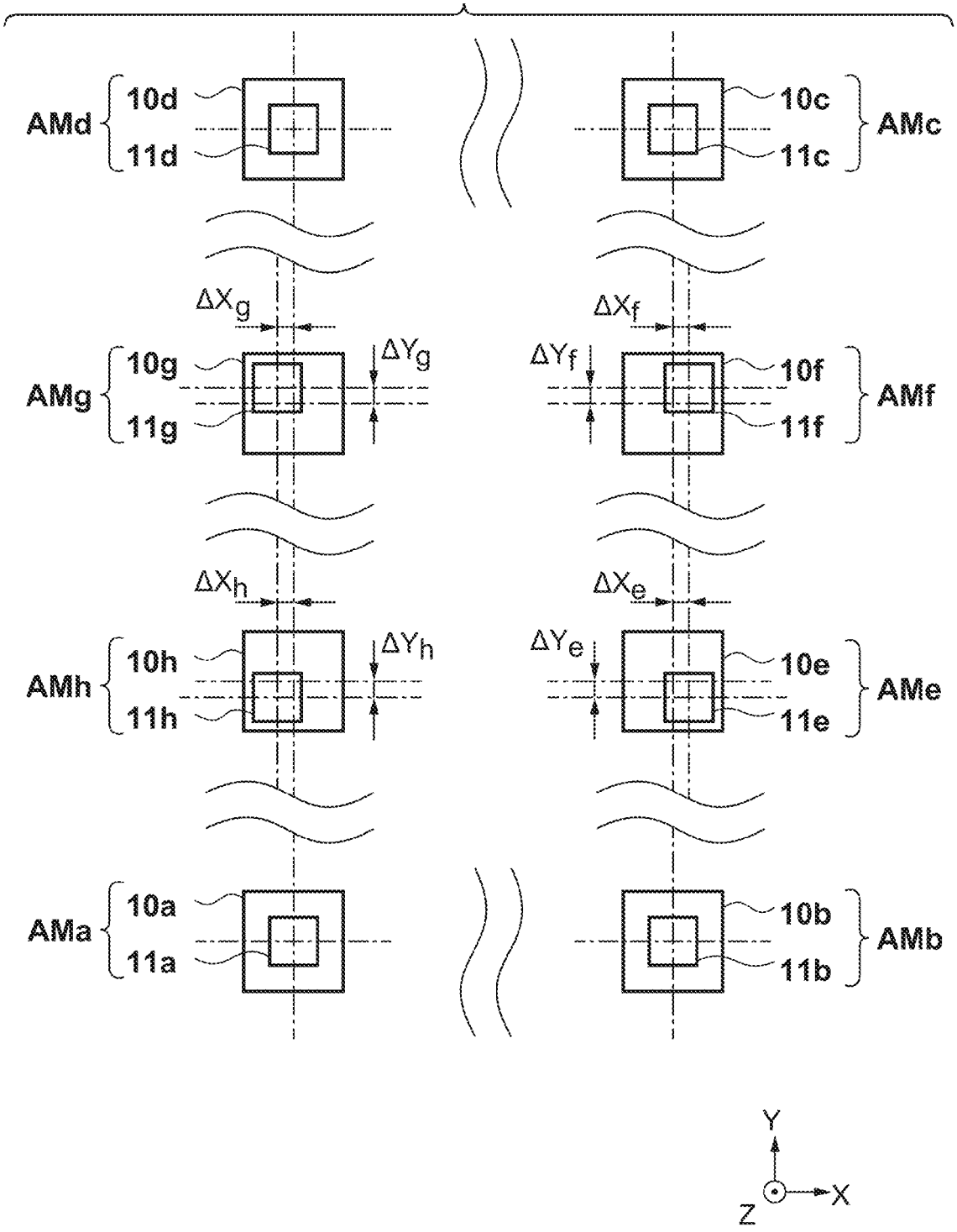


FIG. 9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10d
11d
10c
11c
AMc
ΔXg
ΔXf
AMg
10g
11g
ΔYg
ΔYf
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11f
AMf
ΔXh
ΔXe
AMh
10h
11h
ΔYh
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AMb
Y
X
Z

FIG. 10

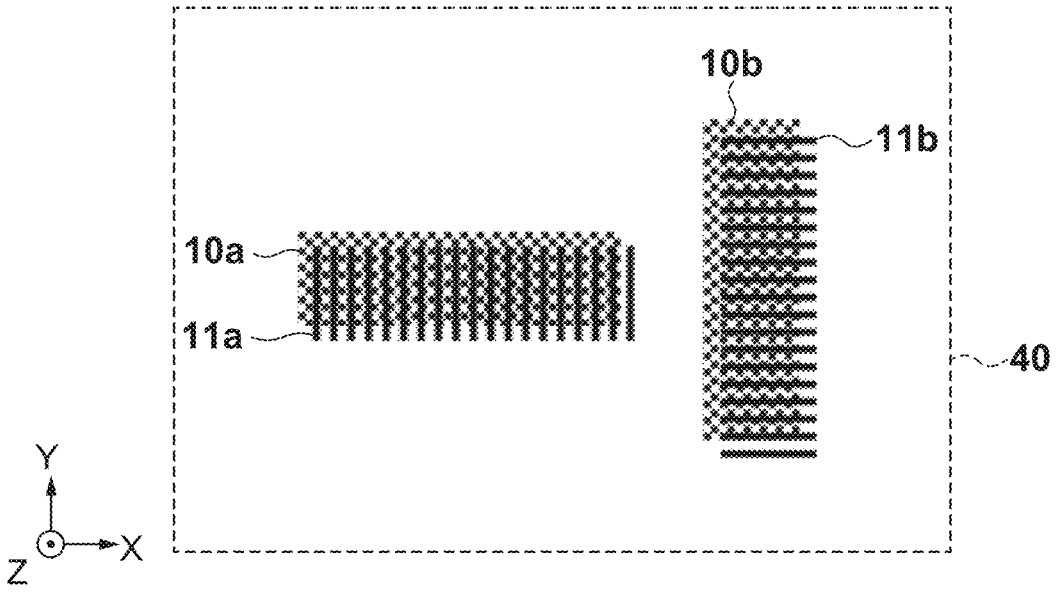


FIG. 11A

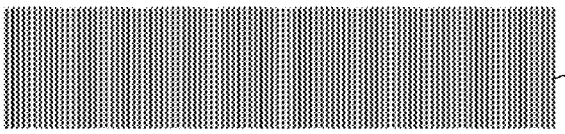


FIG. 11B

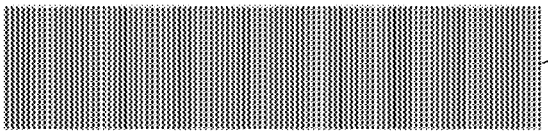


FIG. 11C

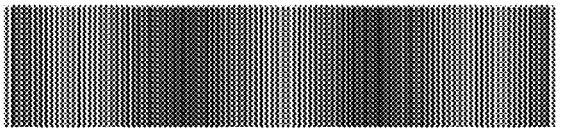


FIG. 11D

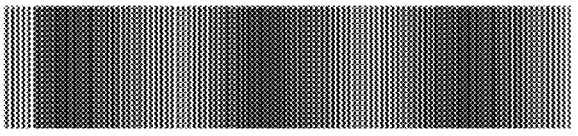


FIG. 12A

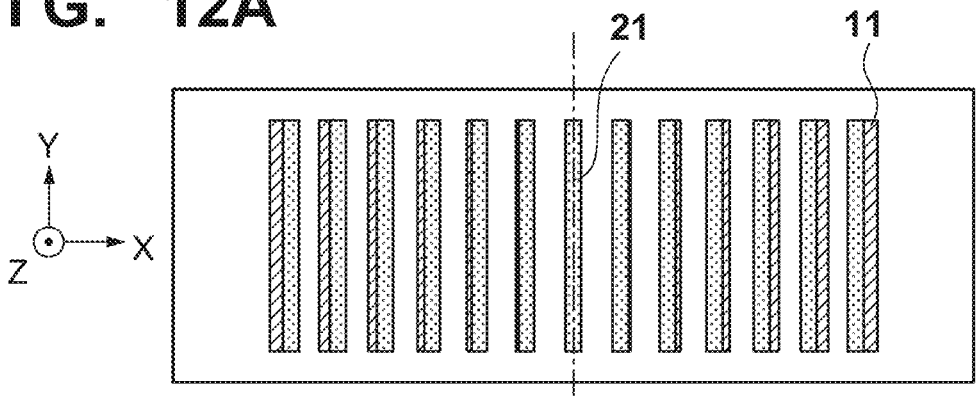


FIG. 12B

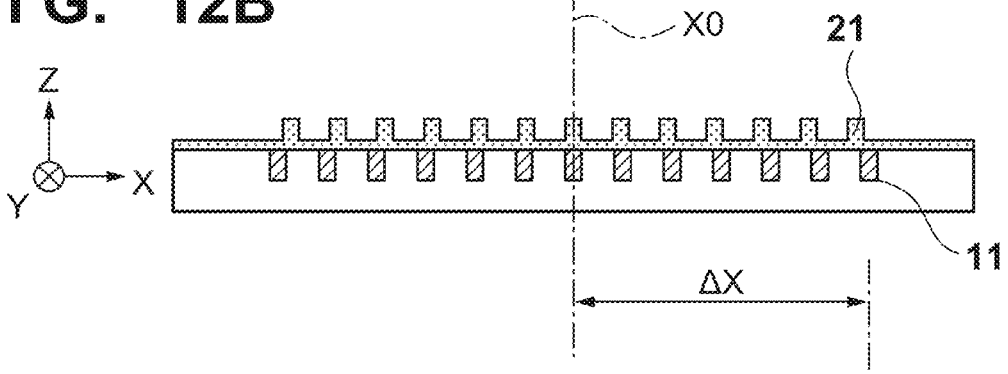


FIG. 12C

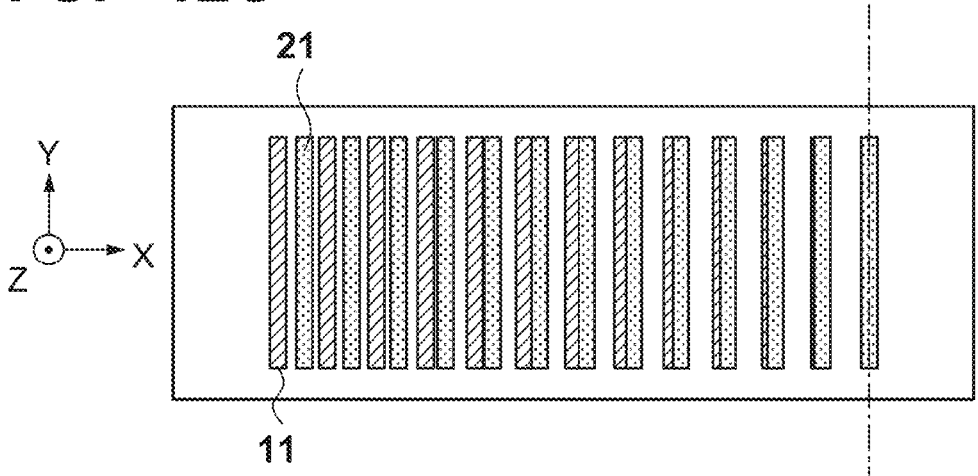


FIG. 12D

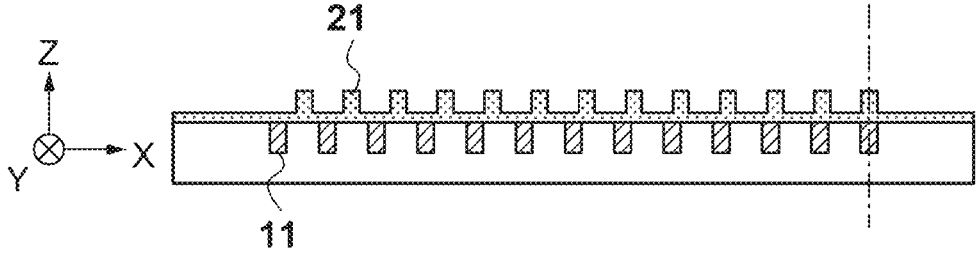


FIG. 13A

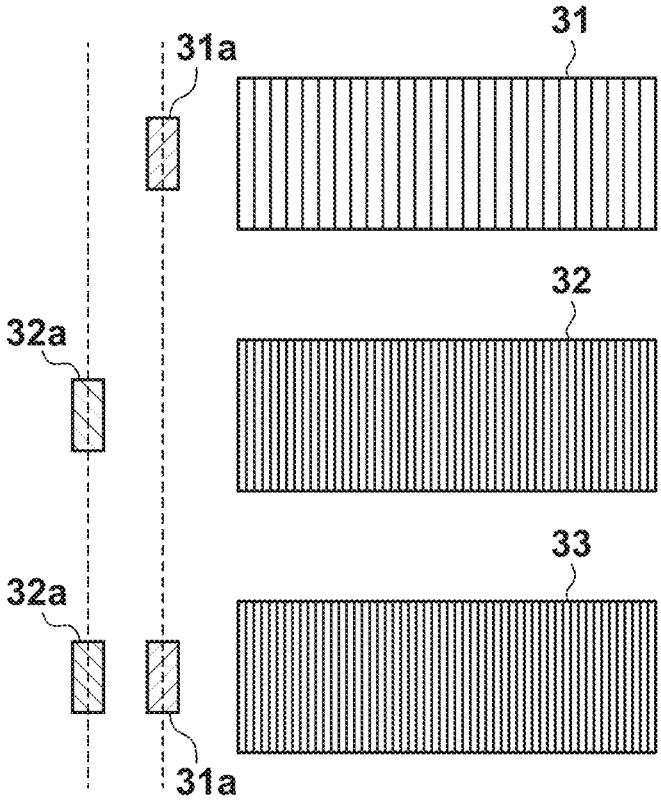


FIG. 13B

FIG. 13C

FIG. 14A

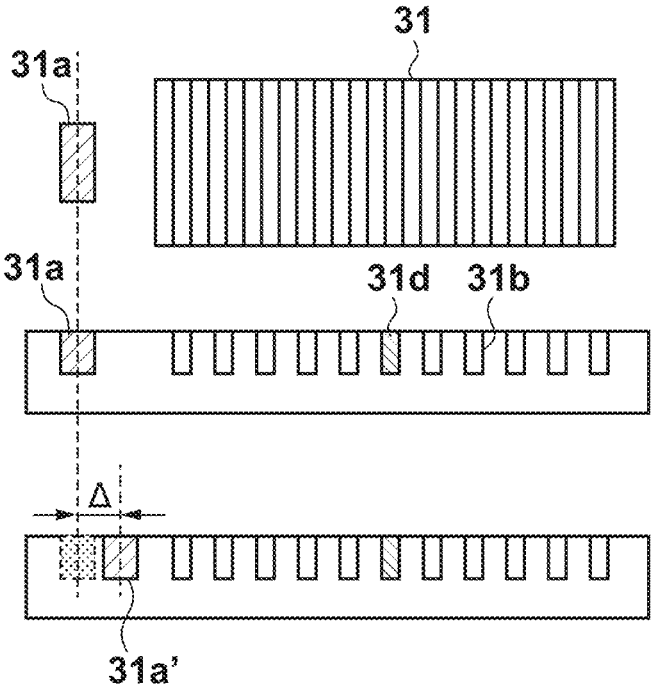


FIG. 14B

FIG. 14C

FIG. 15A

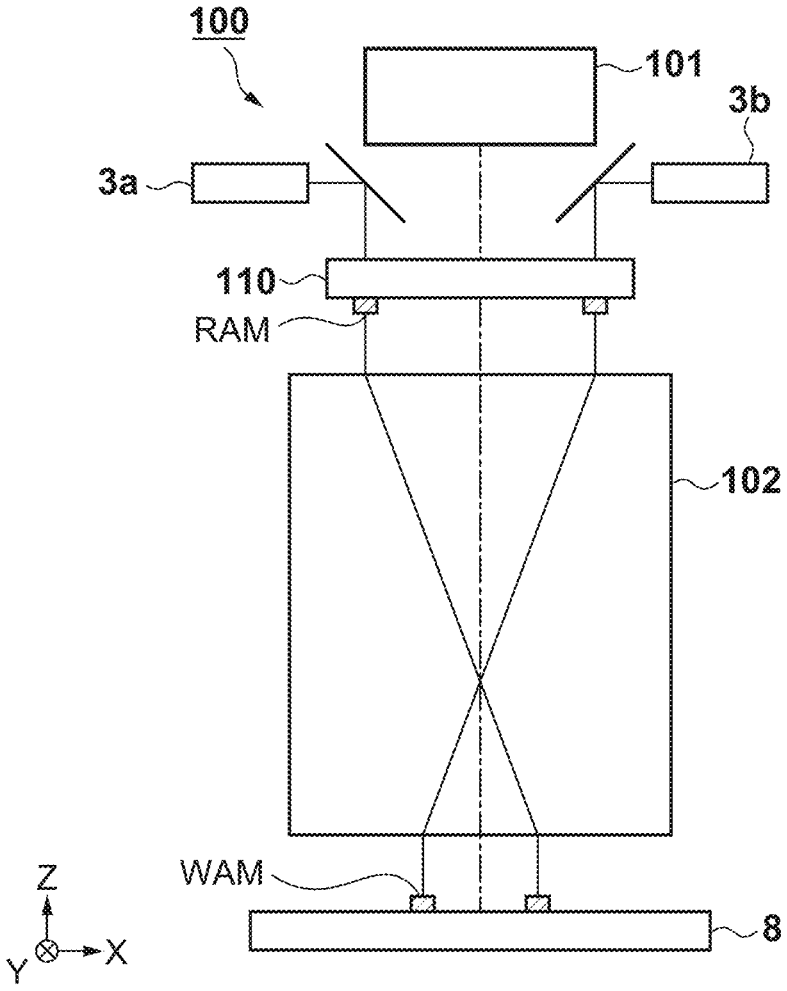
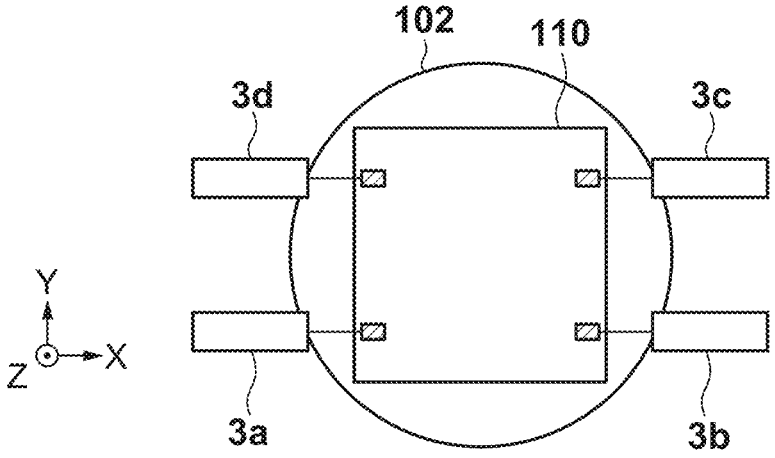


FIG. 15B



LITHOGRAPHY APPARATUS, ALIGNMENT METHOD, AND METHOD OF MANUFACTURING ARTICLE

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a lithography apparatus, an alignment method, and a method of manufacturing an article.

2. Description of the Related Art

As a lithography apparatus used to manufacture a semiconductor device or the like, an imprint apparatus that transfers a pattern formed on a mold serving as an original onto a substrate has received a great deal of attention, in addition to an exposure apparatus that projects the pattern of a mask serving as an original onto a substrate. In the imprint apparatus, a mold with a pattern formed on it and an imprint material supplied onto a substrate are brought into contact with each other, and the imprint material is cured in that state. The mold is separated from the cured imprint material, thereby transferring the pattern of the mold onto the substrate.

In the manufacture of a semiconductor device or the like, a step of overlaying a plurality of patterns on one substrate is necessary. For this reason, in the imprint apparatus, it is important to accurately transfer the pattern of a mold to a shot region formed on the substrate. Japanese Patent No. 4185941 proposes an imprint apparatus that employs a die-by-die alignment method as an alignment method when transferring the pattern of a mold to a shot region. The die-by-die alignment method is an alignment method of detecting marks formed in a shot region and marks formed in a mold and correcting the shift between a substrate and the mold for each shot region on the substrate.

The plurality of marks formed in the shot region sometimes individually have positional shifts due to, for example, manufacturing errors of an original used in the preceding lithography process, deformation of the marks or deformation of the entire substrate caused by a semiconductor process, and the like. In this case, when alignment between the shot region and the pattern of the original is performed based on the detection result of the marks without considering the positional shifts of the marks in the shot region, it may be difficult to accurately transfer the pattern of the original to the shot region.

Japanese Patent Laid-Open No. 2002-196476 proposes a method of aligning a shot region and an original considering manufacturing errors included in the relative positions of the pattern on the original and alignment marks on the original. In the method described in Japanese Patent Laid-Open No. 2002-196476, however, positional shifts that individually occur in the marks formed in the shot region are not taken into consideration.

SUMMARY OF THE INVENTION

The present invention provides a technique advantageous in, for example, accurately transferring the pattern of an original to a shot region formed on a substrate.

According to one aspect of the present invention, there is provided a lithography apparatus for transferring a pattern formed on an original to each of a plurality of shot regions on a substrate, comprising: a detection unit configured to detect a mark provided in the shot region and a mark provided on the original; and a control unit configured to control alignment between the shot region and the pattern of the original based on a detection result of the detection unit, wherein the control unit obtains, from information representing a positional shift amount generated between each mark in the shot region and a corresponding mark on the original when an overlay error between the shot region and the pattern of the original falls within an allowable range, the positional shift amount in a mark to be detected by the detection unit out of a plurality of marks provided in a target shot region to which the pattern of the original is to be transferred, and controls alignment between the target shot region and the pattern of the original such that the mark in the target shot region detected by the detection unit and the mark on the original corresponding to the mark are shifted by the obtained positional shift amount.

Further features of the present invention will become apparent from the following description of exemplary embodiments with reference to the attached drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1**A is a view showing the arrangement of an imprint apparatus according to the first embodiment;

FIG. **1**B is a schematic view showing a detection unit viewed from the upper side of the apparatus;

FIG. **2** is a view showing the arrangement of a deformation unit;

FIG. **3**A is a view for explaining imprint processing of the imprint apparatus according to the first embodiment;

FIG. **3**B is a view for explaining imprint processing of the imprint apparatus according to the first embodiment;

FIG. **3**C is a view for explaining imprint processing of the imprint apparatus according to the first embodiment;

FIG. **4** is a view showing a substrate on which a plurality of shot regions are formed;

FIG. **5** is a view showing partial shots;

FIG. **6** is a view showing the arrangement of a plurality of chip areas and substrate-side marks formed in one complete shot;

FIG. **7** is a view for explaining alignment between a complete shot and a mold;

FIG. **8** is a view for explaining alignment between a partial shot and a mold;

FIG. **9** is a view showing alignment marks in a shot region;

FIG. **10** is a view showing alignment marks according to the second embodiment;

FIG. **11**A is a view for explaining a change in the phase of a moiré fringe;

FIG. **11**B is a view for explaining a change in the phase of a moiré fringe;

FIG. **11**C is a view for explaining a change in the phase of a moiré fringe;

FIG. **11**D is a view for explaining a change in the phase of a moiré fringe;

FIG. **12**A is a view showing the positional relationship between a transferred mark and a substrate-side mark;

FIG. **12**B is a view showing the positional relationship between a transferred mark and a substrate-side mark;

FIG. **12**C is a view showing the positional relationship between a transferred mark and a substrate-side mark;

FIG. **12**D is a view showing the positional relationship between a transferred mark and a substrate-side mark;

FIG. **13**A is a view showing an alignment mark according to the third embodiment;

FIG. **13**B is a view showing an alignment mark according to the third embodiment;

FIG. **13**C is a view showing alignment marks according to the third embodiment;

FIG. **14**A is a view showing alignment marks according to the third embodiment;

FIG. **14**B is a view showing alignment marks according to the third embodiment;

FIG. **14**C is a view showing alignment marks according to the third embodiment;

FIG. **15**A is a view showing the arrangement of an exposure apparatus according to the fourth embodiment; and

FIG. **15**B is a view showing the arrangement of the exposure apparatus according to the fourth embodiment.

DESCRIPTION OF THE EMBODIMENTS

Exemplary embodiments of the present invention will be described below with reference to the accompanying drawings. Note that the same reference numerals denote the same members throughout the drawings, and a repetitive description thereof will not be given.

First Embodiment

In the first embodiment, an example in which an imprint apparatus is used as a lithography apparatus will be described. FIG. **1**A is a view showing the arrangement of an imprint apparatus **50** according to the first embodiment. The imprint apparatus **50** is a lithography apparatus used in the manufacturing process of a semiconductor device or the like. The imprint apparatus **50** performs imprint processing of curing an imprint material on a substrate in a state in which a mold **2** (original) with a pattern formed on it is in contact with the imprint material and separating the mold **2** from the cured imprint material, thereby transferring the pattern onto the substrate. In the imprint apparatus **50** according to the first embodiment, a UV curing resin **9** that cures when irradiated with ultraviolet rays is used as the imprint material, and a photo-curing method of curing the imprint material by irradiation of ultraviolet rays is employed. The imprint apparatus **50** includes a mold holding portion **4** that holds the mold **2**, a substrate holding portion **5** that holds a substrate **8**, an irradiation unit **1** that emits ultraviolet rays, a projection optical system **12**, a detection unit **3**, a control unit **17**, and a resin supply unit **6** that supplies the resin **9** onto the substrate.

The mold **2** has a pattern portion **2***a* in which a pattern to be transferred onto the substrate **8** (resin **9** supplied onto the substrate) is three-dimensionally formed. The mold **2** is made of a material (for example, quartz) capable of passing ultraviolet rays used to cure the resin on the substrate. A plurality of alignment marks (to be referred to as mold-side marks **10** hereinafter) are formed on the mold **2** (pattern portion **2***a*).

The mold holding portion **4** can include a mold chuck that holds the mold **2** by vacuum chuck or electrostatic chuck, and a mold driving unit that drives the mold chuck. The mold driving unit drives the mold chuck (that is, mold) at least in the Z direction (direction (imprint direction) in which the mold **2** is imprinted in the resin **9** on the substrate). The mold driving unit may have a function of driving the mold chuck not only in the Z direction but also in the X direction, Y direction, and θ direction (rotational direction about the Z axis). The shape of the pattern portion **2***a* of the mold **2** may be different from the target shape due to manufacturing errors, thermal deformation, or the like. To cope with this, the mold holding portion **4** includes a deformation unit **16** that deforms the pattern portion **2***a* by applying forces to a plurality of points of the side surfaces of the mold **2**. FIG. **2** is a view showing the arrangement of the deformation unit **16**. As shown in FIG. **2**, the deformation unit **16** includes a plurality of chuck portions **16***a* that chuck the side surfaces of the mold **2**, and a plurality of actuators **16***b* that apply forces to the side surfaces of the mold **2** via the chuck portions **16***a*. When the deformation unit **16** applies forces to the plurality of points of the side surfaces of the mold **2**, the mold **2** can be deformed such that the pattern portion **2***a* obtains a shape close to the target shape. The deformation unit **16** may apply heat to the mold **2** so as to deform it such that the pattern portion **2***a* obtains a shape close to the target shape.

The substrate **8**, onto which the pattern of the mold **2** is to be transferred, includes, for example, a single-crystal silicon substrate or an SOI (Silicon On Insulator) substrate. The resin supply unit **6** (to be described later) supplies the resin onto the substrate **8**. A plurality of shot regions **8***a* are formed on the substrate. A plurality of alignment marks (to be referred to as substrate-side marks **11** hereinafter) are formed in each shot region **8***a*.

The substrate holding portion **5** can include a substrate chuck that holds the substrate **8** by vacuum chuck or electrostatic chuck, and a substrate driving unit that drives the substrate chuck. The substrate driving unit drives a substrate stage (that is, substrate **8**) at least in the X direction and Y direction (directions perpendicular to the imprint direction). The substrate driving unit may have a function of driving the substrate stage not only in the X direction and Y direction but also in the Z direction and θ direction (rotational direction about the Z axis).

The projection optical system **12** is arranged above the mold **2**, and projects the images of the mold-side marks **10** and the images of the substrate-side marks **11** onto a projection plane **13** of the projection optical system **12**. The projection optical system **12** includes a beam splitter **14**. The beam splitter **14** is an optical member that selectively reflects or passes light depending on its wavelength, and is designed to, for example, reflect ultraviolet rays for curing the resin **9** and pass light (visible light or infrared rays) used to illuminate the mold-side marks **10** and the substrate-side marks **11**. For example, a dichroic mirror or a dichroic prism is used as the beam splitter **14**.

The irradiation unit **1** emits ultraviolet rays to cure the resin supplied onto the substrate **8**. In the first embodiment, the irradiation unit **1** is arranged on a side of the projection optical system **12**, and irradiates the beam splitter **14** of the projection optical system **12** with light. The light reflected by the beam splitter **14** irradiates the pattern portion **2***a* in a predetermined shape. The detection unit **3** is arranged above the projection optical system **12**. The detection unit **3** illuminates the mold-side marks **10** and the substrate-side marks **11** via the projection optical system **12**, and observes the images of the mold-side marks **10** and the images of the substrate-side marks **11** projected onto the projection plane **13** of the projection optical system **12**. The detection unit **3** can thus detect the relative positions of the mold-side marks **10** and the substrate-side marks **11**. The detection unit **3** may be unable to detect the mold-side marks **10** and the substrate-side marks **11** simultaneously. For example, the detection unit **3** may individually obtain the positions of the mold-side marks **10** and the substrate-side marks **11** relative to a reference position set in the detection unit **3**, thereby detecting their relative positions.

FIG. **1**B is a schematic view showing the detection unit **3** viewed from the upper side of the apparatus. In the first embodiment, four detection units **3***a* to **3***d* are arranged above the projection optical system **12**. Each of the four detection units **3***a* to **3***d* is configured to observe the substrate-side mark **11** formed in the shot region **8***a* together with the mold-side mark **10**. For this reason, out of the plurality of substrate-side marks **11** formed in the shot region **8***a*, four substrate-side marks **11** can simultaneously be observed using the four detection units **3***a* to **3***d*. The detection units **3***a* to **3***d* are configured to be individually movable in the XY direction (planar direction parallel to the surface of the substrate). For this reason, even when the positions of the substrate-side

marks **11** to be detected by the detection units **3***a* to **3***d* change because of a change in the shape of the shot region **8***a*, it is possible to individually move the detection units **3***a* to **3***d* in the XY direction and detect the substrate-side marks **11**, as will be described later.

The control unit **17** includes a CPU and a memory, and controls the entire imprint apparatus **50** (units of the imprint apparatus **50**). In the first embodiment, the control unit **17** controls imprint processing and processing associated with it. For example, when performing imprint processing, the control unit **17** controls alignment between the mold **2** and the substrate **8** based on the detection result of the detection unit **3**. In addition, when performing imprint processing, the control unit **17** controls the deformation unit **16** such that the pattern portion **2***a* of the mold **2** obtains a shape close to the target shape.

The resin supply unit **6** supplies (coats) the imprint material onto the substrate. As described above, in the first embodiment, the UV curing resin **9** that cures when irradiated with ultraviolet rays as its nature is used as the imprint material. The resin **9** to be supplied from the resin supply unit **6** onto the substrate can appropriately be selected in accordance with various conditions in the manufacturing process of a semiconductor device. The amount of the resin to be discharged from the resin supply unit **6** can appropriately be decided in consideration of the thickness or density of the pattern to be formed in the resin on the substrate.

Imprint processing of the imprint apparatus **50** according to the first embodiment having the above-described arrangement will be described with reference to FIGS. **3**A to **3**C. As shown in FIG. **3**A, the control unit **17** causes the resin supply unit **6** to supply the resin **9** to a target shot region **8***b* to which the pattern of the mold **2** is to be transferred. Since the resin **9** (imprint material) generally used is volatile, it is supplied to the target shot region **8***b* immediately before imprint processing. If the volatility of the resin **9** is low, the resin **9** may be coated to the entire substrate surface in advance by spin coating. When the resin **9** is supplied to the target shot region **8***b*, the control unit **17** causes the detection unit **3** to detect the relative positions of the substrate-side marks **11** and the mold-side marks **10**, and aligns the target shot region **8***b* with the pattern of the mold **2**. The alignment is done by, for example, causing the deformation unit **16** to deform the pattern portion **2***a* or causing the substrate driving unit to adjust the position of the substrate **8**.

After aligning the target shot region **8***b* and the pattern of the mold **2**, the control unit **17** controls the mold driving unit to move the mold **2** in the −Z direction and bring the pattern portion **2***a* of the mold **2** into contact with the resin **9** on the substrate, as shown in FIG. **3**B. At this time, an elapse of a predetermined time is waited in the state in which the pattern portion **2***a* is in contact with the resin **9**. The resin **9** supplied onto the substrate can thus sufficiently fill the pattern of the mold **2**. When the mold **2** is made of a transparent material such as quartz, and the refractive index difference between the mold **2** and the resin **9** is small, the detection unit **3** may be unable to detect the mold-side marks **10** formed in a three-dimensional pattern in the state in which the mold **2** and the resin **9** are in contact. In this case, a substance whose refractive index or transmittance is different from that of the mold **2** may be coated to the mold-side marks **10**. This makes it possible to change the refractive index of the mold-side marks **10** and cause the detection unit **3** to detect the mold-side marks **10** even in the state shown in FIG. **3**B.

When the predetermined time has elapsed in the state in which the pattern portion **2***a* and the resin **9** are in contact, the control unit **17** causes the irradiation unit **1** to irradiate the resin **9** on the substrate with light via the mold **2**. The control unit **17** controls the mold driving unit to move the mold **2** in the +Z direction and separate the mold **2** from the resin **9** on the substrate. The pattern of the mold **2** can thus be transferred to the target shot region **8***b*, as shown in FIG. **3**C. In the target shot region **8***b*, the mold-side marks **10** are also transferred together with the pattern of the mold **2** to form transferred marks **21**.

The plurality of shot regions **8***a* arranged on the substrate **8** in the imprint apparatus **50** having the above-described arrangement will be described next. FIG. **4** is a view showing the substrate **8** on which the plurality of shot regions **8***a* are formed. Referring to FIG. **4**, rectangles indicated by thick lines represent the shot regions **8***a*, and rectangles indicated by thin lines represent chip areas Ci. A plurality of chip areas Ci (six chip areas in the first embodiment) are formed in each shot region **8***a*. In recent years, even when only one chip area Ci is included in a shot region arranged in the peripheral portion of the substrate **8**, the pattern of the mold **2** is required to be transferred to the chip area Ci to raise the yield of chip areas Ci available from one substrate **8**. It is therefore necessary to accurately align the chip area Ci and the mold **2**.

The shot regions **8***a* arranged in the peripheral portion of the substrate **8** include the periphery of the substrate, and are therefore formed on the substrate **8** while being partially lost. The shot region **8***a* including at least one chip area Ci and partially lost when arranged in the peripheral portion of the substrate **8** will be referred to as a partial shot Sp (second shot region) hereinafter. On the other hand, the shot region **8***a* including all chip areas Ci and formed on the substrate **8** into the same shape as the pattern of the mold **2** without being partially lost will be referred to as a complete shot Sc (first shot region) hereinafter. Referring to FIG. **4**, the shot regions **8***a* in which all six chip areas Ci are represented by open rectangles indicate the complete shots Sc. The shot regions **8***a* in which at least one chip area Ci is hatched indicate the partial shots Sp. The hatched chip area Ci indicates an area (valid chip area) as a prospective chip that forms a product without including the periphery of the substrate **8**. The shot region **8***a* having the same shape as the pattern of the mold **2** means not a shot region having the same outer shape but a shot region including a region where the entire pattern of the mold **2** is to be transferred.

Valid chip areas in the partial shot Sp will be described with reference to FIG. **5**. FIG. **5** is a view showing partial shots Sp**1** and Sp**2** shown in FIG. **4**. In the partial shot Sp**1**, chip areas C**1** to C**4** and C**6** except a chip area C**5** are valid chip areas. On the other hand, in the partial shot Sp**2**, the chip areas C**2** to C**6** except the chip area C**1** are valid chip areas. As described above, the arrangement of the valid chip areas in the partial shot Sp changes depending on the arrangement position of the partial shot on the substrate.

The arrangement of the six chip areas Ci and the substrate-side marks **11** formed in one shot region **8***a* will be described next with reference to FIG. **6**. FIG. **6** is a view showing the arrangement of the plurality of (six) chip areas Ci and the substrate-side marks **11** formed in one complete shot Sc. As shown in FIG. **6**, scribe lines used to cut the chip areas Ci are provided between the plurality of chip areas in the shot region **8***a*. A plurality of alignment marks AMa to AMl are provided on the scribe lines in correspondence with the four corners of each chip area Ci. Each of the alignment marks AMa to AMl is defined to be formed by overlaying the mold-side mark **10** on the substrate-side mark **11**. In this way, the plurality of alignment marks AMa to AMl are provided for one shot region. For this reason, even when the number or positions of valid chip areas in the shot region changes, alignment marks

to be detected by the detection unit can be selected in accordance with the number or positions of valid chip areas.

Alignment with the mold **2** in the complete shot Sc and the partial shot Sp will be described with reference to FIGS. **7** and **8**. FIG. **7** is a view for explaining alignment between the complete shot Sc and the mold **2** (pattern portion **2***a*). In the complete shot Sc, since the whole shot region **8***a* is formed on the substrate **8**, the alignment marks AMa to AMd are selected as alignment marks to be detected by the detection unit **3**. The alignment marks to be detected by the detection unit **3** are selected such that the distances between the alignment marks become long. This is because such alignment mark selection makes it possible to accurately detect components such as the magnification component and the rotation component of the shot region **8***a*. The control unit **17** arranges the detection units **3***a* to **3***d* at positions where the selected alignment marks AMa to AMd can be detected, respectively, and causes the detection units **3***a* to **3***d* to detect the alignment marks AMa to AMd, respectively. The control unit **17** controls the deformation unit **16** and the substrate driving unit based on the detection results of the detection units **3***a* to **3***d*, thereby aligning the complete shot Sc and the mold **2**.

FIG. **8** is a view for explaining alignment between the partial shot Sp**1** and the mold **2** (pattern portion **2***a*). In the partial shot Sp**1**, the chip area C**5** includes the periphery **8***b* of the substrate **8**, and the substrate-side mark **11** in the alignment mark AMc is not formed on the substrate. Hence, in the partial shot Sp**1**, the alignment mark AMf is selected as an alignment mark to be detected by the detection unit **3** in place of the alignment mark AMc. The control unit **17** arranges the detection unit **3***c* at a position where the selected alignment mark AMf can be detected, and causes the detection unit **3***c* to detect the alignment mark AMf. The control unit **17** causes the detection units **3***a*, **3***b*, and **3***d* to detect the alignment marks AMa, AMb, and AMd, respectively, as in the complete shot Sc. The control unit **17** controls the deformation unit **16** and the substrate driving unit based on the detection results of the detection units **3***a* to **3***d*, thereby aligning the partial shot Sp and the mold **2**. Alignment of the partial shot Sp**1** has been described above with reference to FIG. **8**. In remaining partial shots Spn as well, alignment is performed by the same method.

As described above, in the imprint apparatus **50**, the alignment marks to be detected by the detection unit **3** are selected in accordance with the number or positions of chip areas Ci included in the shot region **8***a*. However, the plurality of substrate-side marks **11** in the shot region **8***a* may individually have positional shifts due to, for example, manufacturing errors of the mold **2** used in the preceding lithography process, deformation of the substrate-side marks **11** or the substrate **8** caused by a semiconductor process, and the like. The plurality of mold-side marks **10** formed on the mold **2** may also individually have positional shifts due to, for example, manufacturing errors. In this case, when alignment between the shot region **8***a* and the mold is performed without considering the positional shifts of the substrate-side marks **11** or the positional shifts of the mold-side marks **10**, it may be difficult to accurately transfer the pattern of the mold **2** to the shot region **8***a*. To present this, the imprint apparatus **50** according to the first embodiment performs alignment between the shot region **8***a* and the mold **2** (pattern portion **2***a*) in consideration of the positional shifts of the substrate-side marks **11** on the shot region **8***a*. Alignment in the imprint apparatus **50** according to the first embodiment will be described below with reference to FIG. **9**.

FIG. **9** is a view showing the alignment marks AMa to AMh in the shot region **8***a*. The alignment marks AMa to AMh indicate so-called Box in Box marks in which the substrate-side marks **11** are arranged inside the mold-side marks **10**. Referring to FIG. **9**, in each of the alignment marks AMa to AMd selected at the time of alignment of the complete shot Sc, the center of the mold-side mark **10** matches the center of the substrate-side mark **11**. At this time, assume that the overlay error between the shot region **8***a* and the pattern of the mold **2** falls within the allowable range. Actually, positional shifts often occur in the alignment marks AMa to AMd as well. However, the above assumption is made for an easy description. On the other hand, the alignment marks AMe to AMh selectable at the time of alignment of the partial shot Sp individually have positional shifts even in a state in which the overlay error between the shot region **8***a* and the pattern of the mold **2** falls within the allowable range. That is, in each of the alignment marks AMe to AMh, the substrate-side mark **11** and the mold-side mark **10** shift relative to each other. The relative positional shift amounts (X direction, Y direction) in the alignment marks AMe to AMh are (ΔXe, ΔYe), (ΔXf, ΔYf), (ΔXg, ΔYg), and (ΔXh, ΔYh), respectively, as shown in FIG. **9**.

As described above, assume that the overlay error between the shot region **8***a* and the pattern of the mold **2** falls within the allowable range in the state of the alignment marks AMa to AMh shown in FIG. **9**. In this case, at the time of alignment of the complete shot Sc, the overlay error can be made to fall within the allowable range by matching the center of the substrate-side mark **11** with the center of the mold-side mark **10** in each of the alignment marks AMa to AMd. On the other hand, at the time of alignment of, for example, the partial shot Sp**1**, the alignment mark AMf is used, as shown in FIG. **8**. Hence, the control unit **17** controls alignment between the partial shot Sp**1** and the mold **2** (pattern portion **2***a*) such that the substrate-side mark **11** and the mold-side mark **10** shift by the positional shift amount (ΔXf, ΔYf) in the alignment mark AMf. The overlay error between the partial shot Sp**1** and the pattern of the mold can be made to fall within the allowable range by controlling alignment in this way. In the above description, positional shifts occur in the alignment marks AMe to AMh when the overlay error between the shot region **8***a* and the pattern of the mold **2** falls within the allowable range. In fact, positional shift amounts (ΔX, ΔY) are often generated in all of the alignment marks AMa to AMl.

To do the above-described alignment, the imprint apparatus **50** according to the first embodiment has information representing the positional shift amount generated between each substrate-side mark **11** and a corresponding mold-side mark **10** when the overlay error between the shot region **8***a* and the pattern of the mold **2** falls within the allowable range. That is, the imprint apparatus according to the first embodiment has, for each alignment mark AM, the positional shift amount (positional shift amount between the substrate-side mark **11** and the mold-side mark **10**) in the alignment mark AM. The information is stored in, for example, the memory of the control unit **17**.

In the imprint apparatus **50** according to the first embodiment, the control unit **17** selects the substrate-side marks **11** to be detected by the detection unit **3** out of the plurality of substrate-side marks **11** provided in the target shot region **8***b* in accordance with the number or positions of valid chip areas included in the target shot region **8***b*. Next, the control unit **17** obtains positional shift amounts corresponding to the selected substrate-side marks **11** from the information representing the positional shift amounts in the respective alignment marks AM. The control unit **17** causes the detection unit **3** to detect the relative positions of the selected substrate-side marks **11** and the mold-side marks **10** corresponding to them, and con-

trols alignment between the target shot region **8***b* and the mold **2** such that the detected relative positions are shifted by the obtained positional shift amounts. This makes it possible to accurately transfer the pattern of the mold to the target shot region **8***b* even when the substrate-side marks **11** or mold-side marks **10** individually have positional shifts.

The method of obtaining information representing the positional shift amount in each alignment mark AM will be described here. The information can be obtained using, for example, a transfer result obtained by transferring the pattern of the mold **2** to the complete shot Sc. After the pattern of the mold **2** is transferred to the complete shot Sc, the control unit **17** detects the transferred marks **21** and the substrate-side marks **11** formed in the complete shot Sc using the detection units **3***a* to **3***d*. This allows the control unit **17** to obtain the positional shift amount in each alignment mark AM, that is, the positional shift amounts between the substrate-side marks **11** and the mold-side marks **10**. Even when the complete shot Sc and the mold **2** are aligned using the alignment marks AMa to AMd, the overlay error between the complete shot Sc and the pattern of the mold **2** may fall outside the allowable range. In this case, since marks to be used to measure the overlay error are normally provided on the shot region **8***a* and the mold, the control unit **17** measures the overlay error using the marks. The control unit **17** can thus obtain the positional shift amount in each alignment mark AM based on the relative positions of the substrate-side marks and the mold-side marks detected using the detection units **3***a* to **3***d* and the measured overlay error. The overlay error may be measured using a measuring unit configured to measure the overlay error and provided in the imprint apparatus **50** or using a device outside the imprint apparatus.

A plurality of complete shots Sc exist in the substrate, as shown in FIG. **4**. Hence, the positional shift amounts in the alignment marks AMa to AMl may be obtained for each of the plurality of complete shots Sc, and the average value of the positional shift amounts may be calculated for each alignment mark. The average values of the positional shift amounts can be stored in the imprint apparatus **50** (control unit **17**) as the information and updated in every imprint processing of the complete shot Sc. When performing imprint processing for a plurality of substrates **8**, the positional shift amounts may be obtained throughout the plurality of substrates **8**, instead of obtaining the positional shift amounts in the first substrate **8**.

Second Embodiment

In the first embodiment, a method of obtaining the positional shift amount in each alignment mark using Box in Box marks as alignment marks has been described. In the second embodiment, a method of obtaining the positional shift amount in an alignment mark using grating patterns as alignment marks will be described.

FIG. **10** is a view showing alignment marks according to the second embodiment. As shown in FIG. **10**, a mold-side mark **10** can include a grating pattern **10***a* for X direction measurement and a grating pattern **10***b* for Y direction measurement. A substrate-side mark **11** can include a grating pattern **11***a* for X direction measurement and a grating pattern **11***b* for Y direction measurement. In an imprint apparatus **50**, a detection unit **3** observes the mold-side marks **10** and the substrate-side marks **11** in an overlaid state. The grating pattern **10***a* (**10***b*) of the mold-side mark **10** and the grating pattern **11***a* (**11***b*) of the substrate-side mark **11** are configured to have slightly different intervals. For this reason, when the detection unit **3** observes diffracted light in a state in which the grating pattern **10***a* (**10***b*) of the mold-side mark is overlaid on the grating pattern **11***a* (**11***b*) of the substrate-side mark, a moiré fringe (moiré image) is obtained. At this time, the phase of the moiré fringe changes depending on the relative positions of the grating patterns. For this reason, the relative positions of the substrate-side mark **11** and the mold-side mark **10** can be detected by observing the moiré fringe. As shown in FIG. **10**, the grating patterns (**10***a* and **11***a*) for X direction measurement and the grating patterns (**10***b* and **11***b*) for Y direction measurement are simultaneously put in a field **40** of view of the detection unit **3**. At this time, moiré fringes for alignment in the X and Y directions can simultaneously be observed, and the relative positions of the substrate-side mark **11** and the mold-side mark **10** in the X and Y directions can be detected from the phases of the moiré fringes.

A change in the phase of a moiré fringe will be described here with reference to FIGS. **11**A to **11**D. FIGS. **11**A to **11**D are views for explaining a change in the phase of a moiré fringe. FIG. **11**A shows a grating pattern **31** of the mold-side mark **10**. FIG. **11**B shows a grating pattern **32** of the substrate-side mark **11**. FIGS. **11**C and **11**D show results obtained by overlaying the grating pattern **31** on the grating pattern **32**. As shown in FIGS. **11**A and **11**B, the grating patterns **31** and **32** are configured to have different intervals. For this reason, when the detection unit **31** is overlaid on the grating pattern **32**, a moiré fringe including bright portions and dark portions which are alternately arranged can be generated in accordance with the interval difference, as shown in FIG. **11**C. In the moiré fringe, the positions of the bright portions and the dark portions change as the relative positions of the grating patterns **31** and **32** change. For example, when the grating patterns **31** and **32** are relatively shifted in the X direction, the moiré fringe shown in FIG. **11**C changes to that shown in FIG. **11**D. Since the change in the moiré fringe reflects the change in the relative positions of the grating patterns **31** and **32** in an enlarged pattern, the detection unit **3** can accurately detect the relative positions of the mold-side mark **10** and the substrate-side mark **11** even when the resolution of a projection optical system **12** is low.

A method of detecting the relative positions of the mold-side mark **10** and the substrate-side mark **11** using a transferred mark **21** formed by transferring the mold-side mark **10** to the shot region will be described next. FIGS. **12**A to **12**D are views showing the positional relationship between the transferred mark **21** and the substrate-side mark **11**. In FIGS. **12**A and **12**B, the transferred mark **21** is formed on the substrate-side mark **11** in a state in which the center of the transferred mark **21** is placed on the center of the substrate-side mark **11**. FIG. **12**A is a view showing the substrate-side mark **11** and the transferred mark **21** viewed from the Z direction. FIG. **12**B is a sectional view (X-Z sectional view). In the transferred mark **21** formed in this way, a moiré fringe having a symmetric phase with respect to a center X0 of the transferred mark **21** is observed by the detection unit **3**. On the other hand, in FIGS. **12**C and **12**D, the transferred mark **21** is formed on the substrate-side mark while being shifted. FIG. **12**C is a view showing the substrate-side mark **11** and the transferred mark **21** viewed from the Z direction. FIG. **12**D is a sectional view (X-Z sectional view). In the transferred mark **21** formed in this way, a moiré fringe having a phase whose peak is located at a position shifted from X0 by ΔX is observed by the detection unit **3**. It is therefore possible to detect the positional shift amount between the transferred mark **21** and the substrate-side mark **11**, that is, the positional shift amount between the mold-side mark **10** and the substrate-side mark **11** by observing the moiré fringe.

The step of detecting the positional shift amount between the mold-side mark **10** and the substrate-side mark **11** using the transferred mark **21** is executed for each of alignment marks AMa to AMl in a complete shot Sc. More specifically, in the imprint apparatus **50**, when transfer of the pattern of a mold **2** to the complete shot Sc ends, and the mold **2** is separated from the complete shot Sc, detection units **3***a* to **3***d* observe the transferred marks **21**. The imprint apparatus **50** can detect the positional shift amounts between the mold-side mark **10** and the substrate-side mark **11** based on the phase of the moiré fringe obtained from the transferred mark **21** and the substrate-side mark **11**. When detecting the positional shift amount, the overlay error between the complete shot Sc and the pattern of the mold **2** to be transferred on it may be taken into consideration.

Third Embodiment

In the third embodiment, another method of obtaining the positional shift amount in an alignment mark using grating patterns as alignment marks will be described.

FIGS. **13**A to **13**C are views showing alignment marks according to the third embodiment. FIG. **13**A shows a mold-side mark **10**. FIG. **13**B shows a substrate-side mark **11**. FIG. **13**C shows a result of overlaying the mold-side mark **10** on the substrate-side mark **11**. The mold-side mark **10** includes a grating pattern **31**, and a confirmation pattern **31***a* (coarse detection mark) used to confirm the position of the grating pattern **31**. The substrate-side mark **11** includes a grating pattern **32** having an interval different from that of the grating pattern **31** of the mold-side mark **10**, and a confirmation pattern **32***a* used to confirm the position of the grating pattern **32**. Each of the grating patterns **31** and **32** is configured to have a predetermined period. For this reason, a moiré fringe formed when the relative positions of the grating patterns **31** and **32** shift by an integer multiple of the period is the same as that before the shift of the relative positions. That is, when the relative positions of the mold-side mark **10** and the substrate-side mark **11** are detected based on only the moiré fringe formed by the grating patterns **31** and **32**, an error may occur in the detection result. Hence, it is important to set the relative positions of the grating patterns **31** and **32** within one period. For this purpose, the mold-side mark **10** and the substrate-side mark **11** according to the third embodiment include the confirmation patterns **31***a* and **32***a*, respectively. The confirmation patterns **31***a* and **32***a* are configured to have a detection range wider than that of the moiré fringe, although the detection accuracy is lower than that of the moiré fringe. When the confirmation patterns **31***a* and **32***a* having such a structure are detected by the detection unit **3**, the relative positions of the grating patterns **31** and **32** can be set within one period, and the relative positions of the mold-side mark **10** and the substrate-side mark **11** can accurately be detected.

When the relative positions of the confirmation pattern **31***a* (**32***a*) and the grating pattern (**32**) equal the design values, the relative positions of the mold-side mark **10** and the substrate-side mark **11** can accurately be detected by the above-described method. However, the relative positions of the confirmation pattern **31***a* (**32***a*) and the grating pattern (**32**) may have a deviation from the design values due to manufacturing errors of the mold **2**, or the like. This state will be described with reference to FIGS. **14**A to **14**C. FIG. **14**A is a view showing the arrangement of the grating pattern **31** and the confirmation pattern **31***a* of the substrate-side mark **11** viewed from the Z direction. FIG. **14**B is a sectional view. In FIG. **14**B, the grating pattern **31** includes a plurality of marks **31***b* arranged at a predetermined interval with respect to a mark **31***d* as the center. The confirmation pattern **31***a* is assumed to be arranged as designed with respect to the grating pattern **31**. On the other hand, in FIG. **14**C, a confirmation pattern **31***a*' is formed at a position shifted from the design value by a shift amount Δ with respect to the grating pattern **31**. When the shift amount Δ is equal to or larger than a ½ period, it is difficult to accurately detect the relative positions of the mold-side mark **10** and the substrate-side mark **11**. Hence, the shift amount Δ is measured in advance in or outside an imprint apparatus **50**, and alignment of the confirmation pattern **31***a* is performed in consideration of the shift amount A. This makes it possible to accurately detect the relative positions of the mold-side mark **10** and the substrate-side mark **11**.

In the third embodiment, a method has been described in which the detection unit **3** detects the confirmation patterns **31***a* and **32***a*, thereby setting the relative positions of the grating patterns **31** and **32** within one period and detecting the relative positions of the mold-side mark **10** and the substrate-side mark **11**. However, the relative positions of the mold-side mark **10** and the substrate-side mark **11** may be detected only by, for example, causing the detection unit **3** to detect the confirmation patterns **31***a* and **32***a*.

Fourth Embodiment

In the above-described embodiments, the imprint apparatus **50** has been exemplified. However, the present invention configured to align a shot region **8***a* and a mold **2** using information representing the positional shift amount in each alignment mark is also applicable to an exposure apparatus (stepper or scanner). In the fourth embodiment, a case where the present invention is applied to an exposure apparatus will be described.

FIG. **15**A is a view showing the arrangement of an exposure apparatus **100** according to the fourth embodiment. An illumination system **101** illuminates a reticle **110** (original) on which a pattern and alignment marks are formed with exposure light emitted by a light source included in it. A projection optical system **102** has a predetermined magnification (for example, ×1), and projects the pattern formed on the reticle **110** onto a substrate **8**. A plurality of alignment marks WAM are formed in a shot region **8***a* formed on the substrate **8** so as to correspond to a plurality of chip areas Ci included in one shot region **8***a*. A plurality of alignment marks RAM are formed on the reticle **110** so as to correspond to the plurality of alignment marks WAM formed in one shot region **8***a*. The alignment marks WAM formed in the shot region **8***a* will be referred to as substrate-side marks, and the alignment marks RAM formed on the reticle **110** will be referred to as reticle-side marks hereinafter. In the exposure apparatus **100**, a plurality of detection units **3** (four detection units **3***a* to **3***d* in the fourth embodiment) are arranged between the reticle **110** and the illumination system **101**, as shown in FIG. **15**B. FIG. **15**B is a schematic view showing the detection unit **3** viewed from the upper side of the apparatus. The exposure apparatus **100** causes the detection units **3***a* to **3***d* to detect the reticle-side marks and the substrate-side marks via the projection optical system **102**, and aligns the shot region **8***a* and the reticle **110**. The alignment is done by, for example, changing the relative positions of the reticle and the substrate or changing the projection magnification of the projection optical system **102**.

In the exposure apparatus **100** according to the fourth embodiment as well, the substrate-side marks or reticle-side marks may individually have positional shifts, as in the imprint apparatus **50** according to the first embodiment. To

cope with this, the exposure apparatus **100** according to the fourth embodiment has information representing the positional shift amount generated between each substrate-side mark and a corresponding reticle-side mark when the overlay error between the shot region **8***a* and the reticle **110** falls within an allowable range, as in the first embodiment. In the exposure apparatus **100** according to the fourth embodiment, substrate-side marks to be detected by the detection unit **3** are selected out of the plurality of substrate-side marks provided in the shot region **8***a* in accordance with the number or positions of valid chip areas included in the shot region **8***a*. Next, positional shift amounts corresponding to the selected substrate-side marks are obtained from the information representing the positional shift amounts in the respective alignment marks. The detection unit **3** detects the relative positions of the selected substrate-side marks and the reticle-side marks corresponding to them, and alignment between the shot region **8***a* and the reticle **110** is controlled such that the detected relative positions are shifted by the obtained positional shift amounts. This makes it possible to accurately transfer the pattern of the reticle **110** to the shot region **8***a* even when the substrate-side marks or reticle-side marks individually have positional shifts.

In the exposure apparatus according to the fourth embodiment, the method of aligning the shot region and the pattern of the reticle is not limited to the die-by-die alignment method, and may be a global alignment method. The global alignment method means global alignment that measures alignment marks in shot regions (sample shot regions) at several points on a substrate and statistically processes the measured values. For example, the present invention is applicable when detecting alignment marks in a sample shot region.

Embodiment of Method of Manufacturing Article

A method of manufacturing an article according to the embodiment of the present invention is suitable for manufacturing an article, for example, a microdevice such as a semiconductor device or an element having a fine structure. The method of manufacturing an article according to this embodiment includes a step of transferring the pattern of an original (mold or reticle) onto a substrate using the above-described lithography apparatus (imprint apparatus or exposure apparatus), and a step of processing the substrate to which the pattern is transferred in the above step. The manufacturing method also includes other known processes (for example, oxidation, deposition, vapor deposition, doping, planarization, etching, resist removal, dicing, bonding, and packaging). The method of manufacturing an article according to this embodiment is advantageous in at least one of the performance, quality, productivity, and production cost of the article, as compared to conventional methods.

While the present invention has been described with reference to exemplary embodiments, it is to be understood that the invention is not limited to the disclosed exemplary embodiments. The scope of the following claims is to be accorded the broadest interpretation so as to encompass all such modifications and equivalent structures and functions.

This application claims the benefit of Japanese Patent Application No. 2013-168334 filed on Aug. 13, 2013, which is hereby incorporated by reference herein in its entirety.

What is claimed is:

1. A lithography apparatus for transferring a pattern formed on an original to each of a plurality of shot regions on a substrate, the lithography apparatus comprising:

a detection unit configured to detect a mark provided in a target shot region to which the pattern of the original is to be transferred and a mark provided on the original; and

a control unit configured to:

control alignment between the target shot region and the pattern of the original based on a detection result of the detection unit;

generate information representing a positional shift amount between a mark in a shot region and a corresponding mark on the original, based on an overlay error on a sampled shot region different from the target shot region, and relative positions between substrate-side marks and original-side marks, when the pattern of the original was transferred to the sampled shot region;

determine, based on the information, a positional shift amount with respect to each mark to be detected by the detection unit out of a plurality of marks provided in the target shot region; and

control alignment between the target shot region and the pattern of the original so that the mark in the target shot region detected by the detection unit and the corresponding mark on the original are shifted by the determined positional shift amount.

2. The apparatus according to claim **1**, wherein the control unit generates the information using a transfer result of the pattern of the original for, out of the plurality of shot regions, a first shot region formed on the substrate so as to have the same shape of the pattern of the original.

3. The apparatus according to claim **2**, wherein the control unit obtains the positional shift amount for the information based on relative positions of each mark in the first shot region and the corresponding mark on the original and an overlay error between the first shot region and the pattern of the original transferred to the first shot region, which is obtained by transferring the pattern of the original to the first shot region at the relative positions, and updates the information in accordance with the positional shift amount.

4. The apparatus according to claim **3**, further comprising:

a measuring unit configured to measure the overlay error,

wherein the control unit causes the measuring unit to measure the overlay error using the first shot region to which the pattern of the original is transferred, obtains the positional shift amount for the information based on the measured overlay error, and updates the information using the obtained positional shift amount.

5. The apparatus according to claim **3**, wherein:

the mark in the shot region and the mark on the original respectively include grating patterns having intervals different from each other, and

the control unit causes the detection unit to detect diffracted light of the grating pattern in the shot region and the grating pattern on the original to obtain the relative positions of each mark in the first shot region and a corresponding mark on the original.

6. The apparatus according to claim **5**, wherein:

the mark in the shot region and the mark on the original respectively include confirmation patterns used to detect the relative positions at an accuracy lower than that of the relative positions obtained from the diffracted light, and

the control unit obtains the relative positions based on the diffracted light and a positional relationship between the confirmation pattern in the shot region and the confirmation pattern on the original.

7. The apparatus according to claim 6, wherein each of the mark in the shot region and the mark on the original includes the grating pattern and the confirmation pattern, and the positional shift amount is obtained based on relative position errors of the grating patterns and the confirmation patterns.

8. The apparatus according to claim 3, wherein:

the mark in the shot region and the mark on the original respectively include grating patterns having intervals different from each other and confirmation patterns used to detect the relative positions at an accuracy lower than that of the relative positions obtained by the grating patterns, and

the control unit obtains the relative positions based on a positional relationship between the confirmation pattern in the shot region and the confirmation pattern on the original.

9. The apparatus according to claim 1, wherein:

the plurality of shot regions include a second shot region including at least one chip area and arranged on a peripheral portion of the substrate so as to be partially lost while including a periphery of the substrate, and

when the second shot region is the target shot region, the control unit causes the detection unit to detect a mark provided for the at least one chip area out of a plurality of marks formed in the second shot region.

10. The apparatus according to claim 1, wherein:

the mark in the shot region and the mark on the original respectively include grating patterns having intervals different from each other, and

the control unit causes the detection unit to detect diffracted light of the grating pattern in the shot region and the grating pattern on the original, thereby obtaining the positional shift amount.

11. A method of manufacturing an article, the method comprising the steps of:

transferring a pattern of an original onto a substrate using a lithography apparatus; and

processing the substrate on which a pattern has been formed,

wherein the lithography apparatus transfers the pattern formed on the original to each of a plurality of shot regions on the substrate, and includes:

a detection unit configured to detect a mark provided in a target shot region to which the pattern of the original is to be transferred and a mark provided on the original; and

a control unit configured to:

control alignment between the target shot region and the pattern of the original based on a detection result of the detection unit;

generate information representing a positional shift amount between a mark in a shot region and a corresponding mark on the original and the pattern of the original, based on an overlay error on a sampled shot region different from the target shot region, and relative positions between substrate-side marks and original-side marks, when the pattern of the original was transferred to the sampled shot region;

determine, based on the information, a positional shift amount with respect to each mark to be detected by the detection unit out of a plurality of marks provided in the target shot region; and

control alignment between the target shot region and the pattern of the original so that the mark in the target shot region detected by the detection unit and the corresponding mark on the original are shifted by the determined positional shift amount.

12. A method of aligning a shot region and an original in a lithography apparatus for transferring a pattern formed on the original to each of a plurality of shot regions on a substrate, the lithography apparatus including a detection unit configured to detect a mark provided in a target shot region to which the pattern of the original is to be transferred and a mark provided on the original, the alignment method comprising:

a generating step of generating information representing a positional shift amount between a mark in a shot region and a corresponding mark on the original, based on an overlay error on a sampled shot region different from the target shot region, and relative positions between substrate-side marks and original-side marks, when the pattern of the original was transferred to the sampled shot region;

a determining step of determining, based on the information, a positional shift amount with respect to each mark to be detected by the detection unit out of a plurality of marks provided in the target shot region; and

a control step of controlling alignment between the target shot region and the pattern of the original so that the mark in the target shot region detected by the detection unit and the corresponding mark on the original corresponding to the mark are shifted by the determined positional shift amount.

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